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Technical Note

High Voltage power supply for BTeV

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Introduction

This document describes the system CAEN is proposing to satisfy the requirements for BTeV's six front-end detector. The system we propose is using the CAEN SY 1527 and its High voltage plug in modules.
To completely fulfill the requirements, some of the units we propose have to be designed using as a starting point some of the already developed plug-in modules; some of them are new boards. All of them will be based on a very well known technology already used, in different "flavors" in the HV units of the company.

1.1 Overview

The SY1527 system is the fully equipped experiment version of a new line of power supply systems which represents CAEN's latest proposal in the matter of High Voltage and Low Voltage Power Supplying. This system outlines a completely new approach to power generation and distribution by allowing the housing, in the same mainframe, of a wide range of boards with different functions, such as High/Low Voltage boards, generic I/O boards (temperature, pressure monitors, etc.) and branch controllers, where the latter are used to control other remote generators and distributors.

Modularity, flexibility and reliability are the key-points of its design, enabling this module to meet the requirements needed in a wide range of experimental conditions. The latter range from those of LHC experiments, in which the features of this model find prior application, to those of other less challenging, but still demanding, High Energy Physics experiments.

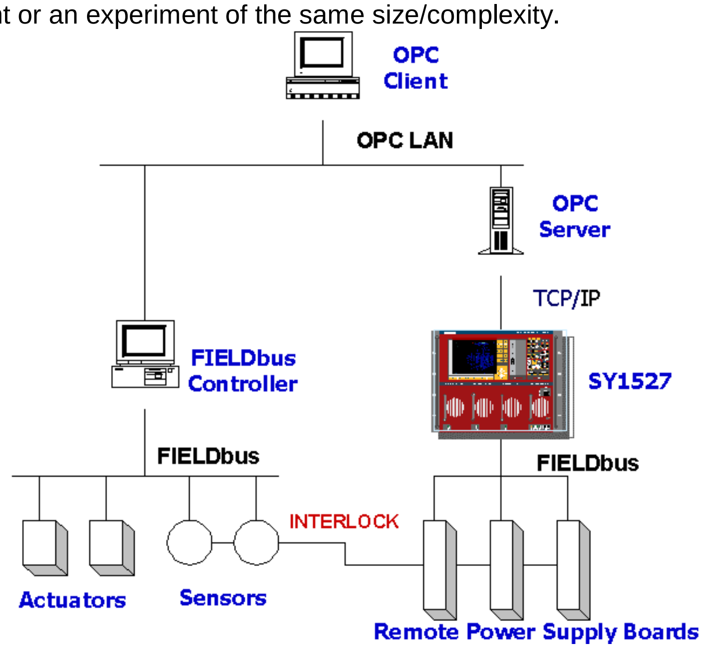
This last generation Power Supplies for LHC experiments has greatly improved the remote control capabilities by a computer network via the standard TCP/IP protocol. The use of TCP/IP allows to implement an easier interfacing of the "HV and LV sub-detector system" with the Detector Control System (DCS). These new generation supplies allow also the generation and distribution of high and low voltage supplies in hostile (radiation and magnetic field) environments. Such a unified system provides the final User and the Software developer with an homogenous and standard interface, thus allowing an easier way of handling the enormous number of channels of LHC experiments.

Moreover, a unified system allows to design any new power supply according to the specific sub-detector requirements simply as a slave board or subsystem, having already all the framework to encapsulate the new subsystems for what concerns System Control.

Thanks to the above described features, including also the housing of a certain amount of "intelligence" on the local and remote supply boards, the SY 1527 find its natural location on a higher hierarchical level in the DCS structure.

The mainframes and boards are able to handle by themselves almost all error and/or interlock occurrences at a hardware level and simply report them to the main DCS. Alarms requiring slower response times can be handled and transferred via TCP/IP.

Following all the above philosophy, CAEN has participated in the last months to several meetings with the ALICE, ATLAS and CMS Detector Control System chairpersons and with the CERN JCOP committee. In particular, a collaboration between CAEN and the JCOP committee is in progress, with the aim of developing, before the end of Y2000, an OPC server that will allow the remote control of all CAEN power supplies. The following figure describes the possible integration of CAEN supplies in an LHC experiment or an experiment of the same size/complexity.



The mainframe is housed in a 19"-wide, 8U-high euro-mechanics rack and hosts four main sections:

- the *Board Section*, with 16 slots to house boards, distributors and branch controllers;
- the *Fan Tray Section*, housing 6 fans disposed on two rows;
- the *Power Supply Section*, which consists of the primary power supply and up to 3 power supply units;
- the *CPU and Front Panel Section* which includes all interface facilities.

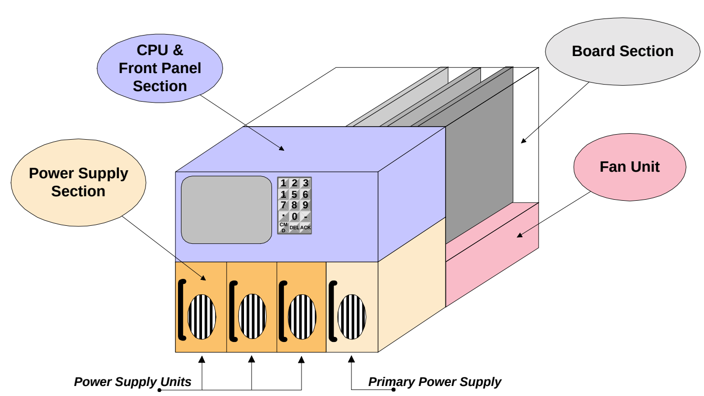


Fig. 1 – Layout of the main mechanical sections of the SY1527 mainframe

DETECTOR SUBSYSTEM	POLARITY	CHANNELS	VOLTAGE RANGE	CURRENT RANGE	PROPOSED HV PLUG-INS
Pixels	Negative	1426	0-1000	10 nA – 10 mA	**A 1810** 24 CH. 1 KV/1µA/100µA/10mA*
Strips	Positive	870	0-1000	10 nA – 10 mA	**A 1810S** 24 CH. 1 KV/4µA/200µA/10mA*
Straws	Positive	3700	~ 0-2200	0-10 µA	**A 1725** 32 CH.2.5 KV/50µA*
RICH	Negative Negative Positive	286 143 143	15 kV-22 kV 10 kV-17 kV 0-100	0-100 nA 0-100 nA 0-10 µA	**A 1524** N 6 Ch. 22KV/1µA* **A 1525** N 6 CH. 17KV/1µA* **A 1519** 12 CH. 250 V/1mA/200µA
EM Cal.	Negative Negative Negative Negative	230 230 230 690	0-400 0-600 0-800 0-1000	0-10 mA 0-2 mA 0-0.5 mA 0-0.1 mA	**A 1706** 32 CH 600 V/ 10mA* **A 1706** 32 CH 600 V/ 10mA* **A 1710** 32 CH. 1 KV/500µA* **A 1710** 32 CH. 1 KV/500µA*
Muon Chambers	Positive	2496	~ 0-2000	0-12 µA	**A 1725** 32 CH 2.5 KV/50 µA*

Detector	**Channels**	**Proposed modules**	**Modularity**	**N° of modules**	**N° of slots**	**N° of crates**
Pixels	1,426	A 1810	24	60	120	8
Strips	870	A 1810S	24	37	74	5
Straws	3,700	A 1725	32	116	232	15
RICH	286	A 15224	6	48	96	6
	143	A 1525	6	24	48	3
	143	A 1519	12	12	12	1
EM Calorimeter	230	A 1706	32	8	16	1
	230	A 1706	32	8	16	1
	230	A 1710	32	8	16	1
	690	A 1710	32	22	44	3
Muon Chambers	2,496	A 1725	32	78	156	10
Total	***10,444***			***421***	***830***	***52***

Table 1: Summary of BTeV High Voltage (*)Common Floating Ground.

1.2 Short Functional description

A block diagram of the SY1527 system is shown in Fig. 2, p.8.

A single crate can host up to 16 Channel Boards, which can be chosen in a wide range of plug-in boards, from standard HV/LV boards and **floating boards** to generic I/O boards monitoring external parameters or branch controllers. All the types of boards can be freely mixed in the same crate so as to fit the user's needs.

Both the Power-On and the Channel-On Enable of the System can be performed either locally or remotely. Remote Enable is performed by sending the proper input signal via the relevant front panel connector.

Each crate may be controlled either locally or remotely. Local control is performed manually through a key-pad, a direction switch and a 7.7" color LCD located on the front panel. A VGA port to connect an external standard VGA monitor and two PS/2 connectors to plug in an external keyboard as well as, in the near future, a mouse pointer allow convenient local operation. Remote control is feasible via the interface connectors located on the front panel. These include a RS232 interface, which can be used to plug in a video terminal (ANSI VT100 or compatible) or a IBM™ PC, and the Ethernet port. The usual HIGH SPEED (H.S.) CAENET interface is also available to daisy-chain more SY1527 crates (up to 99 crates).

A sophisticated Software User Interface is available both in local or remote control, featuring symbolic names for channels, custom status displays and other features designed to help the management of a large number of channels.

Programmable parameters for each power channel include two voltage values (**V0set**, **V1set**) and two current limit values (**I0set**, **I1set**). The switching from one value to the other is performed via two external (NIM or TTL) input levels (VSEL, ISEL). The maximum rate of change of the voltage (Volt/second) may be programmed for each channel. Two distinct values are available, **Ramp-Up** and **Ramp-Down**. Any command to change the voltage will result in a linear voltage increase or decrease with time, the rates being determined by the Ramp-Up or Ramp-Down parameters, respectively.

For the *boards with programmable current hardware protections* the ISET values of the channels represent a software-controlled hardware protection on the channels' currents. In this case the channel cannot draw a current higher than its programmed limit.
For the *boards with fixed current hardware protections*, i.e. boards which have the current hardware protection fixed to a common value for all the channels, the IMON values are used to signal a fault, but the channels can draw a current larger than the ISET values.
In both cases, if a channel tries to draw a current larger than the programmed limit, it is signaled to be in OVERCURRENT. The System detects this state as a fault and reacts according to the setting of the **TRIP** parameter, namely:

1) *TRIP = infinite* **(*constant CURRENT mode*)**
   If the Board has programmable current hardware protections, the output voltage is varied to keep the current below the programmed limit. The channel behaves like a current generator.
   If the Board has fixed current hardware protections, the output current is permitted to exceed the ISET value; the channel behaves like a current generator only if the maximum current value is reached.

2) *TRIP = finite value* **(*TRIP mode*)**

In this case, the channel behaves as in the constant CURRENT mode for a time equal to the finite value set as TRIP parameter, and then it is switched off according to the selected Power-Down option (Kill/Ramp-Down). If the Kill option is selected, the channel will be switched off immediately. If the Ramp-Down option is selected, the voltage will drop to zero at a rate determined by the value of the Ramp-Down parameter programmed for that channel.

Other front panel signals and relevant LEDs are foreseen to signal the channel status, such as OVERVOLTAGE, UNDERVOLTAGE, CHANNEL ON and TRIP. Another set of LEDs warn about possible fault conditions in the system operation (OVER TEMPERATURE, FAN FAILURE, POWER FAILURE).

A RESET can be generated either manually via a front panel button or remotely by sending a proper signal through the relevant connector. In both cases it is possible to reset only the CPU of the system or both the CPU and the boards, depending on the duration of the RESET signal. The System may be instructed to react to a Power On or to a Restart bringing all the channels from zero to the programmed value without the user's intervention via the **Power-On** parameter. If this option is enabled, the System will recover smoothly from a power failure or RESET, automatically restoring the status it had before the power was interrupted. KILL and INTERLOCK functions have been also implemented and allow to drop the channel output voltage to zero, independently from the Ramp-Down parameter set.

In order to protect the System from improper use, a multilevel management of user’s profiles has been foreseen, including the possibility of having password protection for each channel or group of channels. In particular, three different login levels are available: *Guest*, *User* and *Administrator*, each with different levels of access ability to the system parameter monitoring and setting. Moreover, the possibility of defining preferred custom environments is foreseen for each single user.

Daisy-chain configuration of more SY1527 crates can be achieved by using the H.S. CAENET connectors located on the front panel. The chain can be controlled remotely by a SY1527 system configured as CAENET Controller allowing for *Multi-crate Operation*, i.e. the possibility of controlling and monitoring interactively the daisy-chained crates one at a time, either from any one of the SY1527 crates of the chain or from a PC or video terminal externally connected to any one of the crates.

The Ethernet interface further extends the access facilities to the system: it allows the use of a Browser or just a Telnet connection to monitor and control interactively each crate connected to the network. This type of link, which can be reduced to the Customer’s Intranet in order to have secure access, allows to perform remotely a wide range of tasks, such as system debugging, firmware upgrading and even technical support. A special software interface has been developed for the monitoring and setting of system parameters from TCP/IP environment Further remote control interfaces are available on request and can be inserted into the expansion slots on the front panel.

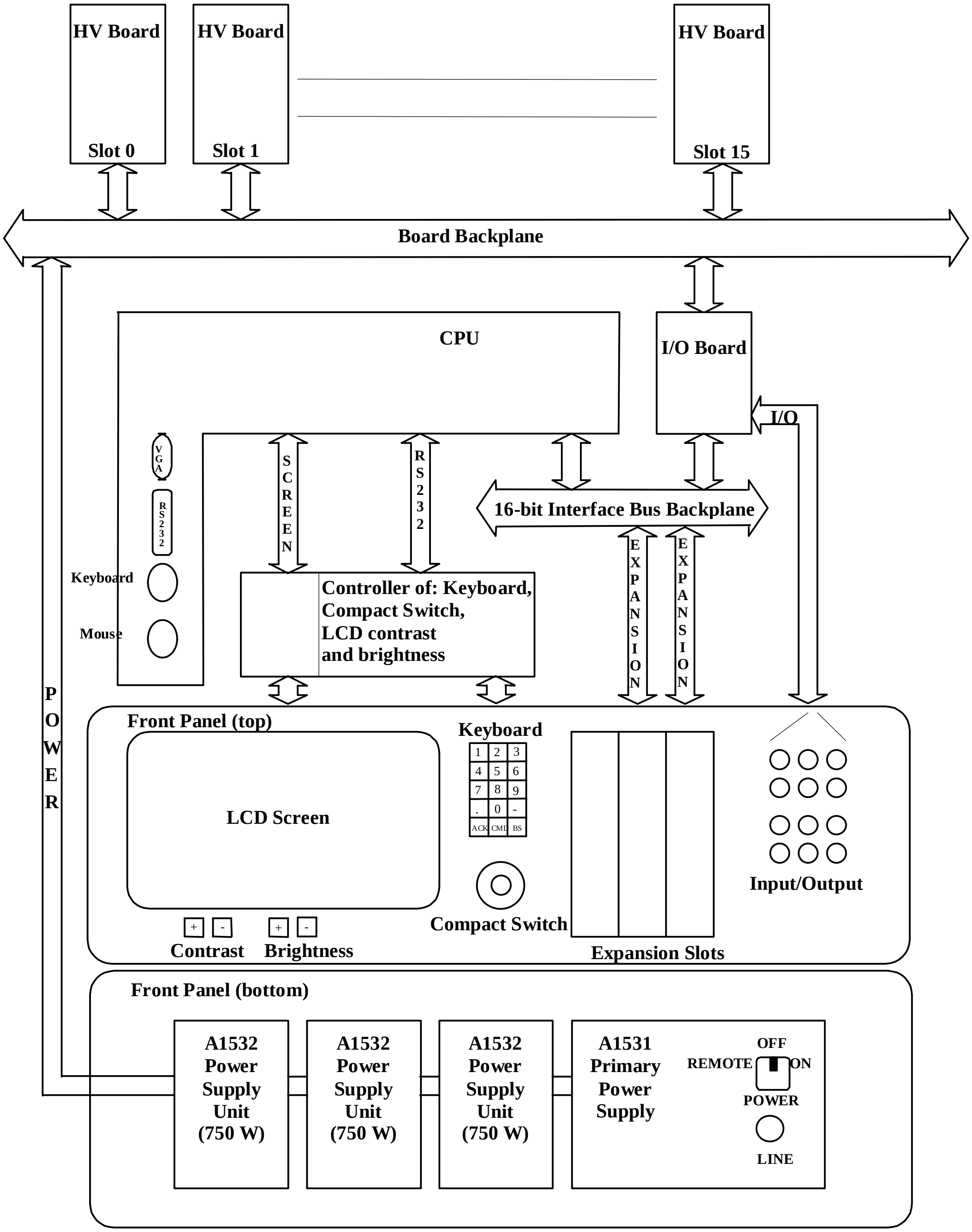


Fig. 2 – Block diagram of the functional parts of the SY1527 system

1.3 System Configuration

To fulfill the requirement of the BTeV procurement options, the system must have 3 different configurations and number of channels. The proposed modules will be the same in all of them, but will have different numbers as well as the three configurations, **A, B** and **C** will differ in the number of necessary main frames.

Detector	**Channels**	**Proposed modules**	**Modularity**	**N° of modules**	**N° of slots**	**N° of crates**
Pixels	1,500	A 1810	24	63	126	
Strips	900	A 1810S	24	38	76	
Straws	4,000	A 1725	32	125	250	
RICH	300	A 15224	6	50	100	
	150	A 1525	6	25	50	
	150	A 1519	12	13	13	
EM Calorimeter	250	A 1706	32	8	16	
	250	A 1706	32	8	16	
	250	A 1710	32	8	16	
	700	A 1710	32	22	44	
Muon Chambers	2,500	A 1725	32	79	158	
Total	***10,950***			***439***	***865***	***55***

Configuration ***A***

Detector	Channels	Proposed modules	Modularity	N° of modules	N° of slots	N° of crates
Pixels	600	A 1810	24	25	50	
Strips	300	A 1810S	24	13	26	
Straws	1,000	A 1725	32	32	64	
RICH	300	A 15224	6	50	100	
	150	A 1525	6	25	50	
	150	A 1519	12	13	13	
EM Calorimeter	250	A 1706	32	8	16	
	250	A 1706	32	8	16	
	250	A 1710	32	8	16	
	250	A 1710	32	8	16	
Muon Chambers	1,000	A 1725	32	32	64	
Total	***4,500***			***222***	***431***	***27***

Configuration ***B***

Detector	Channels	Proposed modules	Modularity	N° of modules	N° of slots	N° of crates
Pixels	300	A 1810	24	13	26	
Strips	100	A 1810S	24	5	10	
Straws	100	A 1725	32	4	8	
RICH	300	A 15224	6	50	100	
	150	A 1525	6	25	50	
	150	A 1519	12	13	13	
EM Calorimeter	250	A 1706	32	8	16	
	250	A 1706	32	8	16	
	250	A 1710	32	8	16	
	250	A 1710	32	8	16	
Muon Chambers	150	A 1725	32	5	10	
Total	***2,250***			***147***	***281***	***18***

Configuration ***C***

The SY 1527 offers two versions of the crate: a master and a slave one. The slave crates can be connected to a master one to realize a cluster of crates with 7 slaves for each master. In this way for the above three configurations, we can have

7 masters and 48 slaves
4 masters and 23 slaves
3 masters and 15 slaves

respectively.

The master crates have all the communication features described in the chapter 1.2 above. The slave crates can be controlled from the remote controller, via the relevant master crates, as an extension of the last one.

This option can be useful to reduce the crates cost.

2 Requirements Common to all Detector Subsystems

All the modules reported in Table 1 have a common floating ground, but the A 1519 which has individual floating channels (two wires per channel). All the channels have individual current limit and voltage output setting. Both voltage applied and current drawn are monitored for every channel.

- **Requirement 2.1-1:**
  - Output voltage settable to 0.1% of the maximum rated voltage.
    - **EXCEED:** all the voltage can be set with a about 0.01% of the rated voltage having a 14 bit precision
  - The output voltage value must be computer readable (See next to last bullet for set value read back requirements).
    - **COMPLY:** the output voltage can be read-back with a 16 bit precision
  - Output current limit settable to 5% of the maximum rated current for the operating range.
    - **COMPLY:** on each channel the user can set a current limit, from 0 up to the full scale with a 14 bit precision.
  - The output current value must be computer readable.
    - **COMPLY:** on each channel the user can read the output current with a 14 bit precision.
  - The recovery from overcurrent must be manually re-settable by either a local panel control button or remotely by a computer command.
    - **EXCEED:** the overcurrent can be reset either automatically, if the channel get out from the OVC condition before the TRIP time set expires, or manually if the OVC condition last after the TRIP time expiring. In the last, the OVC condition can be reset either locally, via the SY 1527 front panel command, or remotely using a computer command
  - Output voltage over-limit and under-limit thresholds must be settable to 5% of the set point voltage.
    - **PARTIALLY COMPLY**: each module has its own over and under limits pre fixed at the factory and function of the module's full scale. In front of an order, we can foresee a new software release allowing the modification of the above said limits.
  - The recovery from overvoltage must be manually re-settable by either a local panel control button or remotely by a computer command.
    - **EXCEED:** the overvoltage is reset automatically if the channel get out from the OVV condition.
  - Output must have on/off control and must be computer-controllable and monitored. There must be local on/off control (see Section 2.9).
    - **COMPLY :** the channel status, ON/OFF, can be set and monitored either locally or remotely channel by channel.
  - Any set point fault must send an "alarm" message to the control computer. A visual and/or audio alarm is also desirable.

    - **COMPLY :** any operational parameter outside the set limits generates an alarm. The alarm is received either via software or via hardware in the general STATUS signal on the front panel. This signal can be programmed to react to any combination of OVC, OVV, UNV or TRIP alarm signal and it can be used to drive an audio/visual signal.
  - All computer settable controls (registers) must be computer readable.
    - **COMPLY:** all the operational parameters, channel by channel and all the settable controls can be accessed either locally or remotely via TCP/IP, RS 232 or HS CAENET.
  - An computer-readable identification method for all different types of plug in units and any calibration constants is required.
    - **EXCEED :** each plug in module is identified and it holds its own calibration parameters. The user can access a restricted area password protected in each plug-in unit to automatically re-calibrate the plug-in itself.
- **Requirement 2.1-2:** Each high-voltage power supply output must be able to have its current limit trip point remotely settable and monitored (computer-controlled). A manual test of this limit is also allowed in addition to the computer test.
  - **COMPLY:** each high voltage channel has its own TRIP settable and readable either locally or remotely (see page 6 for TRIP description)
- **Requirement 2.1-3:** Each high-voltage power supply output must be able to have its overvoltage and undervoltage limit trip points remotely settable and monitored (computer-controlled). A local and manual test of these limits is also allowed in addition to the computer tests.
  - **DOES NOT COMPLY:** each module has its own over voltage and under voltage limits pre fixed at the factory as a function of the module’s full scale. In front of an order, we can foresee a new software release allowing the modification of the above said limits.
- **Requirement 2.1-4:** The absolute accuracy of the computer-controlled settings for output high voltages may be only 1% (or better). The system must be able to be externally and remotely calibrated to the accuracies required in this document and be stable within the required tolerances for a minimum of eight hours over the specified operating range.
  - **EXCEED:** all the plug in modules up to 4 KV full scale have a voltage setting resolution of 250 mV, a Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 0.5 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 0.25 V. The 17 KV and the 22 KV modules have less than 2 V resolution a Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 2 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 1 V. The user can access a restricted area password protected in each plug-in unit to automatically re-calibrate the plug-in itself. The procedure requires an automatic external voltmeter board and a calibrated load.

Input and Environment

- **Requirement 2.2-1:** The supplies must meet all specifications stated over an ambient operating temperature range of 10 ºC to 40 ºC.
  - **EXCEED :** Operating temperature: from 5°C (dry atmosphere) to +40°C; storage temperature : from -20°C (dry atmosphere) to +50°C
- **Observation 2.2-1:** It is preferred that the supplies must operate with a nominal 120 VAC, single phase, 60 Hz input. The supplies must meet the specifications stated over an input voltage range of 105 VAC to 135 VAC, and a frequency variation of 55 Hz to 65 Hz. 208 VAC operation may be acceptable if 120 VAC operation is not normally available with the vendor’s products.

  - **COMPLY:** Power Requirements: Monophase: 88÷264 V a.c., 48÷64 Hz; 38 A Three-phase (*on request*)

- **Requirement 2.2-2:** The supplies must comply with MIL-STD-461B (similar to CE03 specification) for conducted and radiated emissions.
  - **COMPLY:** the system is CE compliant
- **Requirement 2.2-3:** The modules must comply with the ESD requirements IEC 60297-5-103 (IEEE 1101.10) and EN 61000-4-2.
  - **COMPLY:** the system is CE compliant

Output Characteristics & Connectors

- **Requirement 2.3-1:** The output voltages must "float" so that ground is defined at the load. This requirement has safety issues associated with it that are discussed in Section 2.8.
  - **COMPLY:** all the proposed plug in modules are floating in respect to the ground. The plug in modules featuring the common floating ground have all the output of a certain polarity, either positive or negative referred to a common reference that floats with reference to the main frame chassis and mains.
- **Requirement 2.3-2:** The output connectors shall meet safety code as described in FNAL Occupational Health and Safety Document, Chapter 5045: *High Voltage Coaxial Connectors,* Rev. 1/99. This document is available at: http://www-esh.fnal.gov/FESHM/5000/5045.html.
  - **COMPLY:**
- **Requirement 2.3-3:** All output connectors of lower-voltage supplies must be identical and type-keyed as to their output voltage if possible. All output connectors of higher-voltage supplies must also be identical and type-keyed as to their output voltage if possible.
  - **COMPLY:** all the high voltage output connector up to 100 V will be DB 37 type; all the HV output up to 6 KV housed in a double density modules (24/32 channels) will use a multi-pin connector (according to the safety rules the only two connectors we can use are the Radiall P/N 691803002 -52 pins- and the Lemo REDEL SLA.H51.LLZG-51 pins). The HV output connectors from 15 KV to 22 KV will be the Reynolds 167-3517 type or equivalent.
- **Requirement 2.3-4:** On turn-on and turn-off, the ramp rate of each output voltage from off to full on and on to full off, respectively, must be limited to several hundreds of milliseconds minimum.
  - **EXCEED :** each channel has its own ramp-up and ramp-down value programmable either locally or remotely. The max value of the rate of change can vary from 500 V/s (in 1(2)V step) for the higher voltages, up to 50 V/s (in 100 mV step)
- **Requirement 2.3.5:** The peak-to-peak ripple of all outputs must be such that no measurable noise is introduced for the systems described in Section 3.
  - **We are providing the** peak-to-peak ripple value for each plug-in module.
- **Requirement 2.3-6:** The long-term (eight hours minimum) stability must be such that intervention is not required to maintain preset voltage and current levels.
  - **COMPLY:**

- **Requirement 2.3-7:** The impedance of each high-voltage output shall be such that when deactivated, the output capacitors see sufficient impedance in which to discharge such that significant current spikes are eliminated.
    - The parallel output impedance is 100 MΩ for channels ranging from 200 V to 6 KV; for higher voltages, the parallel output impedance is 500 MΩ

Cable Lengths & Remote Sense

- **Requirement 2.4-1a:** If the power supplies are located out of the collision hall, they must operate with output cables up to 80 meters in length.
    - **COMPLY**
- **Requirement 2.4-1b:** If the power supplies are located in the collision hall they must operate with output cables up to 15 meters in length. If this condition exists, then Section 2.5 requirements must be met.
    - **COMPLY**
- **Observation 2.4-1:** If necessary, the high voltage system may operate with remote sense cables. Some issues with safety may need to be addressed (see Section 2.8).
    - **The plug in modules do not require the use of sense cables.**

Radiation Tolerance

- **Requirement 2.5-1:** The high voltage system operating properties must not be degraded by the exposure (over 10 years) to 10 kRad of ionizing particles and a total fluence of $2 \times 10^{12}/\text{cm}^2$ of low energy (< 14 MeV) neutrons. Degradation is defined here as something that no longer lets the system meet all the specification contained in this document.
    - **EXCEED:** CAEN High Voltage power supply plug in modules have been tested under particles radiation to verify their radiation tolerance. It has been tested that, using the correct component selection and circuit solutions, we can provide modules able to be resistant up to 15 kRad of ionizing particles, we tested under proton flux, and able to work under a flux of 10^{12} neutrons/cm^2. Please note, that we never tested the main frame. If the collaboration will decide to use the main frame inside a hard radiation area, some tests on the chassis must be performed.

Packaging

- **Requirement 2.6-1:** The unit must be packaged in a subrack base unit that mounts in standard 19 inch EIA racks.
    - **COMPLY:** 19"-wide, 8U-high Euro-mechanics rack; Depth: 720 mm.
- **Observation 2.6.1:** The base subrack may contain the AC power input, computer monitor interface, and general system safety components. Plug-in units for these functions may also be used. Mean-Time-To-Repair (MTTR) might be reduced if plug-in units are used.
    - **COMPLY: see the description on page 3**

- **Requirement 2.6-2:** The system must be a modular design with the high-voltage plug-in units into the base subrack. The number of channels must be maximized on the subrack level. A desirable minimum number of outputs per subrack is 128. In the case of 10 kV and higher units, this number may be less because of high-voltage distance clearance issues.
  - **COMPLY:** the system has 16 slots and is able to house up to 16 single wide modules or up to 8 double wide modules. The maximum number of channels per main frame is then 256 channels for the units with 32 channels on a double unit, or 64 channels in case of higher voltage outputs (17 and 22 KV). Inside the same main frame different kind of plug-ins units can be inserted to optimize the use of crates and optimize their number.

Maintainability

During data taking, maintenance downtime must be minimized.

- **Requirement 2.7-1:** The system must be designed so that the MTBF (Mean Time Between Failures) of a module is 50,000 hours.
  - **COMPLY:**
- **Requirement 2.7-2:** The system must be designed so that the MTTR (Mean Time To Repair) is less than five minutes after the technician is at the location of the defective unit.
  - **COMPLY:** the system is highly modular and the fault units can be exchanged without switching off the main power supply.
- **Requirement 2.7-3:** If the fault is in a defective module (not the main subrack) the replacement must be accomplished without removing power from the entire subrack.
  - **COMPLY:** the system features the live insertion on all the plug in modules.

Personnel Safety

- **Requirement 2.8-1:** The output ground potential must not exceed 50 V when disconnected from the load ground.
  - **COMPLY:** The output ground potential is 20 V when disconnected from the load ground.
- **Requirement 2.8-2:** Since the output ground is floating, the output must protect personnel with a ground fault interrupt circuit.
  - **COMPLY:** each board has the common floating ground referred to the system ground via Transient Voltage Suppressors of about 20 V (270 A peak) and 100 MΩ in parallel.
- **Requirement 2.8-3:** The power supply, subrack and modules, must follow the guidelines described in Fermilab's ES&H Manual, Chapter 5046 (FESHM5046) and the rules given in Chapter's 4 and 9 of the DOE Handbook of Electrical Safety.
  - **COMPLY:**
- **Requirement 2.8-4:** The modules must comply with the safety ground specifications in IEC 60950 (1991-10) and IEC 61140 (1997-11).
  - **COMPLY:**

On/Off Control, Fault Monitoring & Safety Interlock Provisions

- **Requirement 2.9-1:** Each module must provide external isolated input(s) to be used as an interlock to unconditionally prevent high-voltage outputs from being turned on, either manually or by computer control. This interlock must be fail safe (*e.g.* interlock cable break is a fault). The design of the interlock may impact hot swap and the vendor should discuss this possible conflict.
  - **COMPLY:** each plug in module has an input on the front panel to Enable/Disable the HV generation of the channels housed by that module. In the multipin output connector solution, 2 pins inside the connector, are dedicated to the interlock feature. The interlock is granted by the correct and stable connection of the HV outputs with the corresponding load. If the connection breaks in any point, the HV is switched off. The interlock is also provided to the system in order to give a panic OFF commands acting on the complete system. The system interlock can be daisy chained on all the main frames to disable the complete HV system.
- **Requirement 2.9-2:** Each module must provide one front-panel LED that indicates an internal or external fault condition initiated a disabling of one of its high-voltage outputs (*e.g.,* load overvoltage or overcurrent). The LED must be illuminated only when this disabling condition exists. Any safety interlock to this module must not illuminate the LED.
  - **COMPLY:** in the catalog units, all these signals are related to the main frame and not to the individual channel. For the BTeV collaboration modules, we can foresee a special version of the units featuring these signals on the unit's front panel: one (or more) LED per board to signal a generic "alarm" condition (*e.g.,* load overvoltage or overcurrent).
- **Requirement 2.9-3:** Each type of failure mode must be able to be monitored by computer control. This includes information if the interlock caused the module's outputs to be disabled (see Requirement 2.9-1).
  - **EXCEED:** all the parameters can be monitored included all the alarm conditions. Additionally, the system can provide a trip-in trip-out feature able to switch off group of channels assigned to the same trip-in trip-out line and wired via the front-panel, through different chassis.
- **Requirement 2.9-4:** Each module must provide an external isolated output that can be daisy-chained and that indicates an internal or external fault condition (*e.g.,* overcurrent, over temperature, *etc.*). This output must be able to be used directly as an input to disable the high-voltage outputs of the module or other modules.
  - **PARTIALLY COMPLY:** all the following signals are related to the main frame and not to the individual plug in

OVC: *Mechanical specifications:* 00-type LEMO connector.
Electrical specifications: std. NIM level or TTL level.
Function: at least one channel is in *Over Current*.

UNV: *Mechanical specifications:* 00-type LEMO connector.
Electrical specifications: std. NIM level or TTL level.
Function: at least one channel is in *Under Voltage*.

OVV: *Mechanical specifications:* 00-type LEMO connector.
Electrical specifications: std. NIM level or TTL level.
Function: at least one channel is in *Over Voltage*.

TRIP: *Mechanical specifications:* 00-type LEMO connector.
Electrical specifications: std. NIM level or TTL level.
Function: at least one channel in *Trip* condition.

GEN: *Mechanical specifications:* 00-type LEMO connector.
Electrical specifications: std. NIM level or TTL level.

Function: GENERAL STATUS indication; corresponds to the logic combination, defined by the user, of OVC, UNV, OVV, TRIP.

The user can use all of them to disable the HV generation of a set of crates, or all of them, using the following inputs

KILL: *Mechanical specifications:* 00-type LEMO connector.
Electrical specifications: std. NIM level or TTL level; level active.
Function: KILL from the front panel: it turns all channels off when it is TRUE.

ENABLE: *Mechanical specifications:* 00-type LEMO connector.
Electrical specifications: std. NIM level or TTL level; level active.
Function: if the remote enable mode is selected via the relevant three-position lever switch, it is used to enable the system remotely.

3 Requirements Unique to Each Subsystem

Pixel Detector

The proposed module is **A 1810, 24 Channels 1000V/1µA/100µA/10mA Common Floating Ground**. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 192 channels per main frame. The output connector is Radiall P/N 691803002 multipin connector 52 pin

- **Requirement 3.1-1:** The supply must produce a negative voltage that is adjustable over the range of 0 V to 1000 V. The computer monitor must be accurate to 0.1% of full scale.
    - **COMPLY:** the unit is providing a completely floating output voltage with a 24 channel modularity. The set/monitor resolution is 100 mV and the Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 0.2 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 0.1 V
- **Requirement 3.1-2:** Ripple and noise must be less than 0.1%, peak to peak, of the output over a frequency range of 20 Hz to 20 MHz.
    - **EXCEED:** ripple is less than 30 mVpp in the range from 20 Hz to 20 MHz.
- **Requirement 3.1-3:** Stability of the output voltage (after 30 minute warm up) over an eight-hour period of less than 0.1% from 0 to 40º C.
    - **PARTIALLY COMPLY:** stability of the output voltage is better than 0.01% from 10 to 40 °C , after 30 minute warm up over an eight-hour period .
- **Observation 3.1-1:** The current may be adjusted in three ranges: 10 nA to 1 µA, 400 nA to 100 µA, and 40 µA to 10 mA.
    - **COMPLY:** the three sets of full scale currents can be selected via hardware switches and the setting software readable.
- **Requirement 3.1-4:** The current monitor resolution must be 0.1% of the range setting.
    - **COMPLY:** the current monitor resolution is 1 nA, 100 nA and 10 µA respectively.
- **Requirement 3.1-5:** The manufacturer must provide an alternate quotation for high voltage units listed above that have a peak-to-peak common mode voltage of less than 10 V and a frequency spectrum of ~0 to 100 MHz between the unit output and the load.
    - **EXCEED:** in the specified frequency range, the units have a common mode voltage less than 1 V.

Silicon Strip Detector

The proposed module is **A 1810S, 24 Channels 1000V/4µA/200µA/10mA Common Floating Ground**. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 192 channels per main frame. The output connector is Radiall P/N 691803002 multipin connector 52 pin

- **Requirement 3.2-1:** The supply must produce a positive voltage that is adjustable over the range of 0 V to 1000 V. The computer monitor must be accurate to 0.1% of full scale.

  - **COMPLY:** the unit is providing a completely floating output voltage with a 24 channel modularity. The set/monitor resolution is 100 mV and the Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 0.2 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 0.1 V
- **Requirement 3.2-2:** Ripple {unknown at this time}
  - ripple is less than 30 mVpp in the range from 20 Hz to 20 MHz.
- **Requirement 3.2-3:** Stability {unknown at this time}
  - stability of the output voltage is better than 0.01% from 10 to 40 °C , after 30 minute warm up over an eight-hour period .
- **Observation 3.2-1:** The current may be adjusted in three ranges: 40 nA to 4 µA, 2 µA to 200 µA, and 100 µA to 10 mA.
  - **COMPLY:** the three sets of full scale currents can be selected via hardware switches and the setting software readable.
- **Requirement 3.2-4:** The current monitor resolution must be 0.1% of the range setting.
  - **COMPLY:** the current monitor resolution is 4 nA, 200 nA and 10 µA respectively

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Straw Detector

The proposed module is **A 1725, 32 Channels 2.5 KV/50 µA Common Floating Ground**. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 256 channels per main frame. The output connector is Radiall P/N 691803002 multipin connector 52 pin

- **Requirement 3.3-1:** The supply must produce a positive voltage that is adjustable over the range of ~ 0 V (supply may be a hundred volts or so from zero) to 2200 V. The computer monitor must be accurate to 0.5% of full scale.
  - **COMPLY:** the maximum voltage output is 2500 V floating. The set/monitor resolution is 200 mV and the output voltage can be set and monitor from remote.
- **Requirement 3.3-2:** Ripple {unknown at this time}
  - ripple is less than 30 mVpp in the range from 20 Hz to 20 MHz.
- **Requirement 3.3-3:** Stability {unknown at this time}
  - stability of the output voltage is better than 0.01% from 10 to 40 °C , after 30 minute warm up over an eight-hour period .
- **Requirement 3.3-4:** The current must be adjusted to 1% in the range of 0 to 10 µA.
  - **EXCEED:** the current output limit can be set in the range from 0 to the max, in 10 nA step
- **Requirement 3.3-5:** The current monitor resolution must be 1% of full scale.
  - **COMPLY:** the current output limit can be read out in the range from 0 to the max, in 10 nA *step*

RICH Detector

A 1524, 6 Channels 22 KV/1 µA Common Floating Ground. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 48 channels per main frame. The output connector is Reynolds 167-3517 (N.B. As specified by the manufacturer the 22 KV can be granted only when mated)

A 1525, 6 Channels 17 KV/1 µA Common Floating Ground. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 48 channels per main frame. The output connector is Reynolds 167-3517

A 1519, 12 Channels 250 V/ 1 mA/200 µA Floating. The unit is a single wide unit, consequently a 19" chassis of the SY 1527 can house up to 16 modules for a total of 192 channels per main frame. The output connector is DB 37 (2)

- **Requirement 3.4-1a:** The Type A supply must produce a negative voltage that is adjustable over the range of 15,000 V to 22,000 V. The computer monitor must be accurate to 0.1% of full scale.
    - **EXCEED:** the voltage can be set from 500V up to the max voltage, 22 KV, with 14 bit resolution. The system is able to monitor the output voltage with 16 bit resolution.
- **Requirement 3.4-1b:** The Type B supply must produce a negative voltage that is adjustable over the range of 10,000 V to 17000 V. The computer monitor must be accurate to 0.1% of full scale.
    - **EXCEED:** the voltage can be set from 500V up to the max voltage, 17 KV, with 14 bit resolution. The system is able to monitor the output voltage with 16 bit resolution.
- **Requirement 3.4-1c:** The type C supply must produce a positive voltage that is adjustable over the range of 0 V to 100 V. The computer monitor must be accurate to 0.1% of full scale.
    - **EXCEED:** the voltage can be set from 0V up to the max voltage, 250 V, in 50 mV step. The system is able to monitor the output voltage with 50 mV resolution.
- **Requirement 3.4-2:** Ripple {unknown at this time}
    - For the A 1519 the ripple is less than 30 mVpp in the range from 20 Hz to 20 MHz.
    - For the A 1524 the ripple is less than 200 mVpp in the range from 20 Hz to 20 MHz.
    - For the A 1525 the ripple is less than 200 mVpp in the range from 20 Hz to 20 MHz.
- **Requirement 3.4-3:** Stability {unknown at this time}
    - stability of the output voltage is better than 0.01% from 10 to 40 °C , after 30 minute warm up over an eight-hour period .
- **Requirement 3.4-4:** The module must have a Reynolds Industries P/N167-3517 or equivalent connector for the output high voltage for 17 kV or higher. Any safe connector may be used for the 100V unit.
    - **COMPLY:** the modules A 1524 and A 1525 use the connector P/N167-3517., the A 1519 uses two DB 37 connectors
- **Requirement 3.4-5:** The current must be adjusted to 5% in the range of 0 to 100 µA for the 17 KV or higher units. The 100 V units must have a current range of 0 to 10 µA.
    - **EXCEED:** current limit can be adjusted from 0 to the max value, 1µA, in the A 1524/1525 with a 10 nA resolution; from 0 to the max value, 200 µA, with a 10 nA resolution for the A 1519.
- **Requirement 3.4-6:** The current monitor resolution must be 1% of the range setting for the high voltage units and 10% for the 100 V units.
    - **EXCEED:** current limit can be monitored from 0 to the max value, 1 µA, in the A 1524/1525 with a 10 nA resolution; from 0 to the max value, 200 µA, with a 10 nA resolution for the A 1519.

EM Calorimeter Detector

A 1706, 32 Channels 600V/10mA Common Floating Ground. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 256 channels per main frame. The output connector is multipin connector Radiall P/N 691803002 52 pin

A 1710, 32 Channels 1 KV/500 μA Common Floating Ground. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 256 channels per main frame. The output connector is multipin connector Radiall P/N 691803002 52 pin

- **Requirement 3.5-1a:** The Type A supply must produce a negative voltage that is adjustable over the range of 0 V to 400 V. The computer monitor must be accurate to 0.02% of full scale.
  - **EXCEED:** the unit is providing a completely floating output voltage with a 32 channel modularity. The set/monitor resolution is 100 mV and the Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 0.2 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 0.1 V
- **Requirement 3.5-1b:** The Type B supply must produce a negative voltage that is adjustable over the range of ~0 V to 600 V. The computer monitor must be accurate to 0.02% of full scale.
  - **EXCEED:** the unit is providing a completely floating output voltage with a 32 channel modularity. The set/monitor resolution is 100 mV and the Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 0.2 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 0.1 V
- **Requirement 3.5-1c:** The type C supply must produce a positive voltage that is adjustable over the range of 0 V to 800 V. The computer monitor must be accurate to 0.01% of full scale.
  - **EXCEED:** the unit is providing a completely floating output voltage with a 32 channel modularity. The set/monitor resolution is 100 mV and the Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 0.2 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 0.2 V
- **Requirement 3.5-1d:** The type D supply must produce a positive voltage that is adjustable over the range of 0 V to 1000 V. The computer monitor must be accurate to 0.01% of full scale.
  - **EXCEED:** the unit is providing a completely floating output voltage with a 32 channel modularity. The set/monitor resolution is 100 mV and the Voltage Monitor vs. Output Voltage Accuracy equal to ± 0.3% ± 0.2 V, a Voltage Set vs. Voltage Monitor Accuracy equal to ± 0.3% ± 0.1 V
- **Requirement 3.5-2:** The peak-to-peak ripple must be less than 100 mV.
  - **EXCEED:** ripple is less than 30 mVpp in the range from 20 Hz to 20 MHz.
- **Requirement 3.5-3:** The output must be stable to 0.2 V over a 24-hour period.
  - **COMPLY:** stability of the output voltage is better than 0.01% from 10 to 40 °C , after 30 minute warm up.
- **Requirement 3.5-4:** The current must be adjusted to 0.1% in the range. The following maximum currents are required: 10 mA for the 400 V units, 2 mA for the 600 V units, 0.5 mA for the 800 V units, and 0.1 mA for the 1000 V units.
  - **COMPLY:**
- **Requirement 3.5-5:** The current monitor resolution must be 0.1% of the range for all units.
  - **COMPLY:**
- **Requirement 3.5-5:** The current monitor resolution must be 0.1% of the range for all units.
  - **COMPLY:**

Muon Chambers Detector

The proposed module is **A 1725, 32 Channels 2.5 KV/50 μA Common Floating Ground**. The unit is a double wide unit, consequently a 19" chassis of the SY 1527 can house up to 8 modules for a total of 256 channels per main frame. The output connector is Radiall P/N 691803002 multipin connector 52 pin

- **Requirement 3.6-1:** The supply must produce a positive voltage that is adjustable over the range of ~0 V (supply may be a hundred volts or so from zero) to 2000 V. The computer monitor must be accurate to 0.1% of full scale.
  - **EXCEED:** the maximum voltage output is 2500 V floating. The set/monitor resolution is 250 mV and the output voltage can be set and monitor from remote.
- **Requirement 3.6-2:** Ripple {unknown at this time}
  - ripple is less than 30 mVpp in the range from 20 Hz to 20 MHz.
- **Requirement 3.6-3:** Stability {unknown at this time}
  - stability of the output voltage is better than 0.01% from 10 to 40 °C , after 30 minute warm up over an eight-hour period .
- **Requirement 3.6-4:** The current must be adjusted to 1% in the range of 0 to 12 μA.
  - **EXCEED:** the current output limit can be set in the range from 0 to the max, in 10 nA step
- **Requirement 3.6-5:** The current monitor resolution must be 1% of the range setting.
  - **EXCEED:** the current output limit can be read out in the range from 0 to the max, in 10 nA step